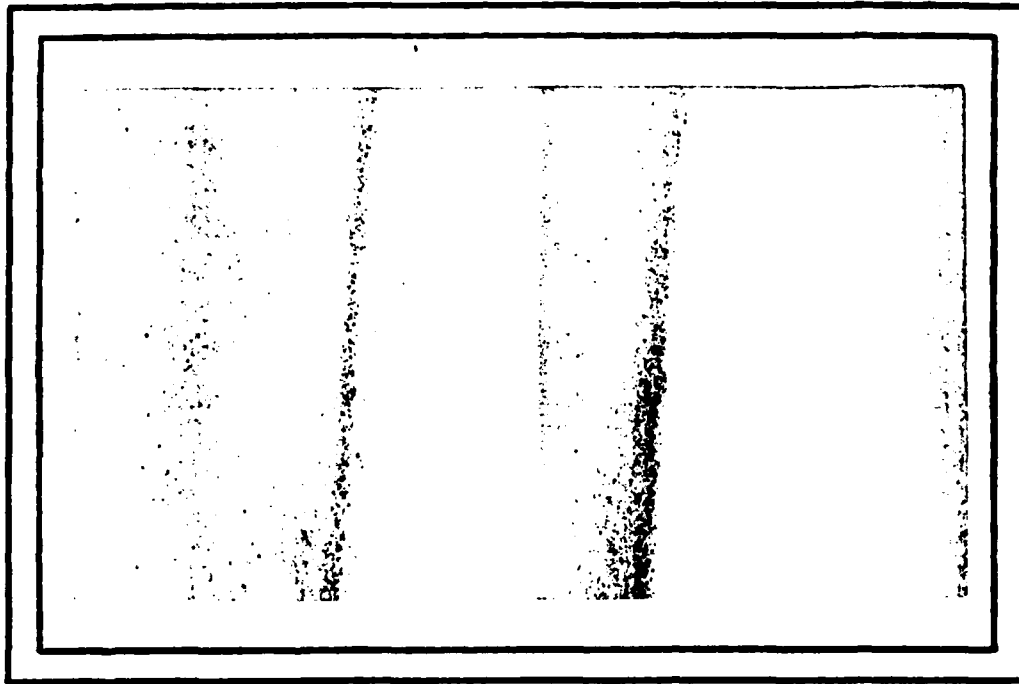


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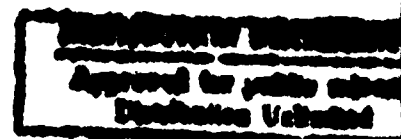
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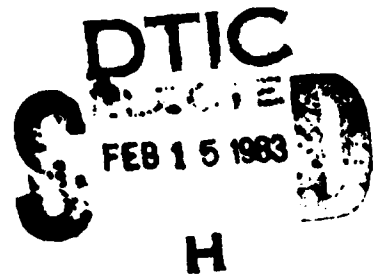
IMAGE REGISTRATION BY COMBINING
FEATURE MATCHING AND GRAY LEVEL CORRELATION

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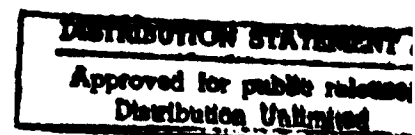
ABSTRACT

A method of image registration based on matching patterns of local features was described in an earlier report. This note describes the use of gray level correlation to handle cases in which feature matching gives ambiguous results. Substantial improvement in matching performance can be achieved at little additional computational cost.



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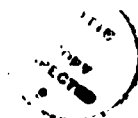
1. Introduction

Image registration is a key step in such applications as multisensor remote sensing, navigation, stereomapping, change detection, and pattern recognition. For a general introduction to the subject see [1].

Classically, image registration is carried out by matching pixel gray levels, e.g., by computing the normalized cross-correlation of the two images being matched [1]. This is a computationally expensive process, is sensitive to geometric distortion, and also tends to yield non-sharp matches. An alternative which is generally less expensive and also yields sharper matches is to extract sets of distinctive, sharply localized features from the two images and then match the resulting patterns of features. Sensitivity to distortion can be reduced by using "relaxation" techniques to determine compatible pairings of the features between the two images. A set of experiments applying this approach to several different types of images is described in [2,3].

One problem with the method in [2,3] is that it depends on extracting sets of more or less corresponding feature points from the two images. If too many of the extracted points do not correspond, the process may fail to discover a reasonable match, or it may detect spurious matches in addition to (or instead of) the correct matches, due to accidental correspondences.

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This note shows how spurious matches can be largely eliminated, without significantly increasing the computational cost, by combining gray level correlation with feature point matching. Experimental results are given using samples of aerial imagery.

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2. Method

The steps in the feature matching approach of [2,3] can be briefly summarized as follows:

- a) Feature points ("corners" at which the gradient magnitude and rate of change of gradient direction are both high) are extracted from both images. Thresholds are adjusted so that the number of extracted points is about the same for both images (about 15 or 20).
- b) Tentative correspondences are determined between pairs of these corner points, based on their orientations, sharpnesses, and contrasts. A relaxation process is used to confirm these correspondences based on the occurrence of correspondences in the appropriate nearby positions.
- c) Each surviving correspondence determines a relative displacement of the two images. If enough of these displacements form a cluster, we conclude that a match between the images has been detected.

Our method is designed to handle the case where more than one cluster of displacements is detected.

Let P, Q be a pair of corresponding points. We pick small windows centered at P and Q ; in our experiments we used 7×7 windows in one image and 15×15 windows in the other. We cross-correlate each small window with the corresponding large one, and check whether there is a correlation peak near the center of the large window. If C is a cluster of corresponding

points, let C' be the subset of this cluster for which this correlation condition is satisfied. Let A' and B' be the largest and second largest of the cluster subsets defined in this way. If $|A'| > k|B'|$, where k is a parameter (>1) and the bars denote cardinality, we say that a match between the images has been found.

3. Results

Figures 1-2 show two pairs of images used in our experiments, as well as the corner points extracted from them. In each figure, the first image is shown on the left; the smaller image that was matched with it is in the lower center position, and the best matching subimage of the first image is in the middle center. (The upper center shows the subimage for which the match was first detected during the search process.) The feature points extracted from each of the small images are shown next to it.

Tables 1-2 show the matching results with and without the use of correlation. Each table shows the correspondences found using feature point matching only. (Part (a) shows them for the upper center/lower center match, and part (b) for the middle center/lower center match.) For each corresponding pair of points (x_i, y_i) and (x_j, y_j) we give the relative displacement (x_d, y_d) , the number(clus) of the cluster to which it belongs, and the displacement (cor-cntr) of its correlation peak relative to the center of the window. We see that when correspondences with badly off-center correlation peaks are eliminated, only one cluster survives.

4. Concluding remarks

These experiments show that local gray level correlation can be used to improve the results of image registration based on feature point matching. Since this correlation is performed on relatively small windows, it adds little to the computational cost, but as we see, it is quite effective in removing the ambiguities that sometimes arise when feature matching is used.

References

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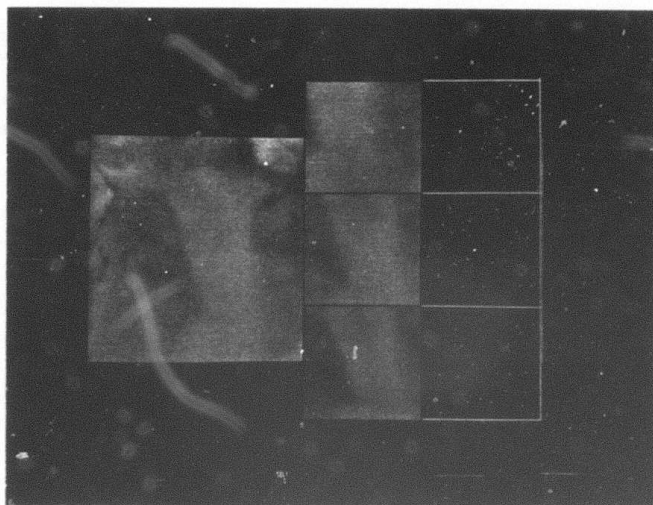


Figure 1

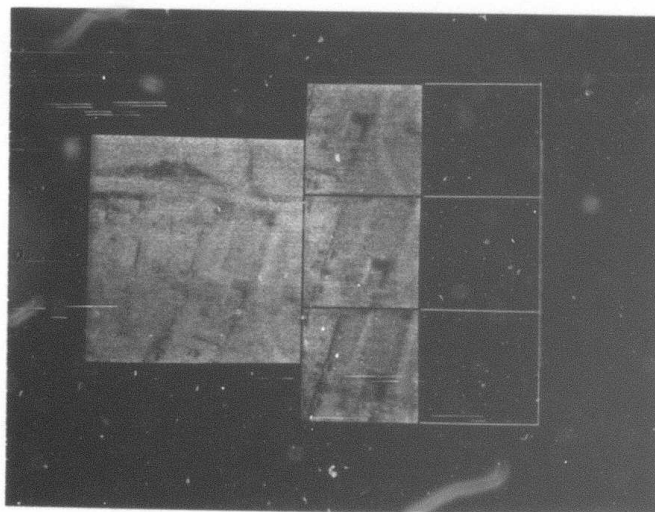


Figure 2

	xi	yi	xj	yj	xd	yd	clus	cor-cntr	
	--	--	--	--	--	--	----	-----	-----
(a)	13	53	20	45	7	-8	1	3	4
	21	46	5	34	-16	-12	0	0	1*
	35	56	18	35	-17	-21	0	-3	-2
	36	47	43	40	7	-7	1	2	2
	52	24	36	5	-16	-19	0	1	2*
	52	37	37	20	-15	-17	0	1	4
	54	54	5	34	-49	-20	2	4	4
	59	60	43	40	-16	-20	0	0	-1*

	xi	yi	xj	yj	xd	yd	clus	cor-cntr	
	--	--	--	--	--	--	----	-----	-----
(b)	13	53	11	56	-2	3	0	0	2*
	21	46	21	51	0	5	0	0	1*
	35	56	34	52	-1	-4	0	-3	-2
	52	24	52	22	0	-2	0	1	2*
	52	37	52	33	0	-4	0	0	2*
	54	54	45	54	-9	0	0	3	3
	59	60	59	57	0	-3	0	0	-1*

Table 1.

	xi	yi	xj	yj	xd	yd	clus	cor-cntr	
	--	--	--	--	--	--	----	-----	-----
(a)	2	12	25	10	23	-2	1	1	3
	3	2	25	2	22	0	1	4	0
	3	54	26	55	23	1	1	4	-4
	29	31	15	2	-14	-29	0	-4	-4
	30	23	11	11	-19	-12	2	0	1*
	35	47	16	35	-19	-12	2	0	0*
	46	23	6	21	-40	-2	3	4	-1
	48	52	35	22	-13	-30	0	-2	4
	55	23	15	21	-40	-2	3	4	-4

	xi	yi	xj	yj	xd	yd	clus	cor-cntr	
	--	--	--	--	--	--	----	-----	-----
(b)	3	37	2	37	-1	0	1	-1	0*
	3	54	3	57	0	3	1	1	2*
	16	10	16	10	0	0	1	0	0*
	30	23	30	24	0	1	1	0	1*
	35	47	35	48	0	1	1	0	0*
	46	23	25	34	-21	11	2	4	-1
	48	52	54	35	6	-17	0	-2	4
	55	23	55	23	0	0	1	0	0*

Table 2.

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